Laser Photocoagulation for Diabetic Macular Edema

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Diabetic macular edema (DME) remains a significant cause of central vision loss in patients with diabetes mellitus. DME is defined as retinal thickening involving the macular area. The edema is caused primarily by a breakdown of the inner blood retinal barrier resulting in leakage of fluid and plasma constituents from abnormally permeable micro-aneurysms, intraretinal microvascular anomalies and dilated retinal capillaries. The visual loss may also be worsened by capillary closure involving the foveal capillary arcade, so called ischemic maculopathy.

Retinal photocoagulation basically involves thermally damaging the abnormal tissues in retina to produce their destruction or inducing adhesions. In this article we will basically discuss the practical & basic techniques of photocoagulation and the proper settings of laser parameters to produce the desired effect and minimize the side effects of laser application. Before we discuss these aspects, it is important to know the fundamentals of retinal photocoagulation.

Mechanism of action

Photocoagulation uses light to coagulate tissue. When energy from a strong light source is absorbed by tissue and is converted into thermal energy, coagulation necrosis occurs with denaturation of cellular proteins as temperature rises above 65 degrees C.

Since the Diabetic Retinopathy Study, technology evolved from using a diffuse Xenon arc to using well-focused laser in photocoagulating retinal tissue in high risk proliferative diabetic retinopathy. Presently, laser retinal photocoagulation is a therapeutic option in several retinal and eye conditions.

Effective retinal photocoagulation depends on how well light penetrates the ocular media on its way to the retinal tissue and how well the light is absorbed by pigment in the target tissue. In retinal tissue, light is absorbed by melanin, xanthophyll or haemoglobin.

Melanin absorbs green, yellow, red and infrared wavelengths; xanthophyll (in the macula) absorbs blue but minimally absorbs yellow or red wavelengths; hemoglobin absorbs blue, green and yellow with minimal red wavelength absorption.

In the ETDRS study, laser photocoagulation reduced the risk of moderate visual acuity loss for all eyes with DME and mild to moderate Non-proliferative diabetic retinopathy by approximately 50%.

Various parameters of photocoagulation

i) Power(its unit is milliwatts or mW)- power needed varies with host of other parameters-

a) Spot size- Larger spot size needs larger power to cause similar photocoagulation effect e.g. with 100μ spot size, just 100 mW power might suffice while if spot size is increased to 200μ, power required would be greater, say 200 mW to cause similar photocoagulation effect.

b) Duration of exposure- Larger exposure time means (normally 0.1 sec is used for average setting) less power required.

c) Clarity of media- hazier media e.g. due to cataract or vitreous hemorrhage means more power required.

d) Pigmentation (melanin) of patient's fundus- Pigmented eyes need less power than Caucasian eyes. Moreover within patient's own fundus, pigmentation varies requiring variable power for different areas. Macular region has maximum melanin pigment and hence absorbs greater energy than surrounding paramacular regions.

iii) Spot size- Already mentioned. Simple rule of thumb in FD-YAG (Frequency Doubled) or Argon green laser with exposure time set at 0.1 sec is to use same number of milli Watts power as the spot size in microns (i.e. for 100ì spot size at 0.1 sec exposure time, 100 mW is the average power required; practically however as the machines get older, it needs higher power to cause similar effect). Larger spot sizes destroy greater retinal thickness.

iv) Wavelength (colour) used- Wavelengths most commonly used are Green as in Frequency-Doubled YAG (FD-YAG with 532 nm) & Argon green (515 nm), Infrared in Diode (810 nm). Now rarely used are krypton red (647 nm), krypton yellow (568 nm). Argon blue (480 nm) is no more used.

When to Treat DME?

The goal of macular laser photocoagulation is to limit vascular leakage through focal laser burns of leaking microaneurysms or grid laser burns in areas of diffuse breakdown of blood retinal barrier. Laser treatment should be considered for patients with clinically significant diabetic macular edema (CSME). Macular edema is considered clinically significant if any oneor any combination of the following is observed :

- Retinal thickening at or within 500 microns from the center of macule.
- Hard exudates at or within 500 microns of the foveal center, if associated with thickening of the adjacent retina.
- A zone or zones of retinal thickening one disc area in size, at least part of which is within one-disc diameter of the foveal center.

How to Evaluate a Patient before Laser Photocoagulation?

CSME is a clinical diagnosis made with slit-lamp biomicroscopy. Macular edema is best evaluated by dilated eye examination using slit-lamp biomicroscopy with a 78 or 90 D lens and/or stereo fundus photography. It is seen as a thickening of the macula with blurring of the underlying choroidal pattern, loss of foveolar light reflex when fovea is involved and presence of cystoid spaces in severe cases.

Fluorescein angiography (FA) prior to laser for CSME is helpful for identifying areas of focal and diffuse leakage and for identifying pathologic enlargement of the foveal avascular zone (ischemic maculopathy), which may be useful in planning treatment.

It is helpful to have the angiogram printout or digital display in the laser room to better direct therapy.

Ocular coherence tomography (OCT) is desirable and should always be done if available. It is helpful to detect subtle edema, quantify it, look for serous macular detachment and to follow the course of edema after treatment.2

Advantages of Laser photocoagulation

Photocoagulation decreases the release of vasoproliferative factors by conversion of hypoxic foci into anoxic areas and leaking vascular anomalies into inert scars.

This relieves the retina of edema and improves its function and also causes the regression of new vessels, inhibiting further hemorrhages.

The procedure does however save the center of the patient's sight. Laser may also slightly reduce colour and night vision.

This treatment slows the growth of new abnormal blood vessels that have developed over a wide area of the retina.

Decision Making

Points that need to be considered before treatment are

- **Fluorescein Angiography**

Is there discrete or deep diffuse leakage ?

Is there macular ischemia ?

- **Optical Coherence Tomogram**

Are there vitreomacular interface anomalies?

How thick is the macula? Is there a subclinical serous macular detachment?

- **What is the visual acuity**

Laser treatment works best in eyes with discrete areas of leakage on FA

- Mild to moderate thickening on OCT
- No vitreo-macular interface abnormalities on OCT
- Visual acuity good or with only a mild to moderate decrease

Pharmacotherapy works best in eyes with -

- diffuse leakage on FA with moderate to severe thickening,
- cystoid macular oedema (CME) or a serous macular detachment on OCT,
- moderate to severe decrease in visual acuity

Systemic work- up

Control of diabetes (Blood sugar, HbA1c),

- Blood pressure
- cholesterol is essential for the success of this treatment.

The recommended values for HbA1c, B.P. and LDL Lipoproteins are <7%, <130/80 mm Hg and < 100mg/dl respectively.

Treatment considerations

Informed Consent: should be obtained from every patient, stressing that the treatment is designed to stabilize or slow the rate of vision loss rather than to improve vision.. Patients with very good vision (ie 6/6 visual acuity) should also be treated if they have CSME. Treatment is unlikely to restore the visual acuity once it goes down, so treatment prior to visual loss is sometimes appropriate. The patient should be informed about the need for periodic follow up, repeated FA/OCT and the possibility of more laser treatment. Eyes with CSME which need PRP for severe NPDR/PDR should always undergo treatment for the macular edema first followed by panretinal photocoagulation (PRP) after 4-6 weeks.

Choice of lens-Laser photocoagulation requires a contact lens which is placed in the eye under topical anaesthesia with the aid of a viscous solution like goniosol or methylcellulose eye drops.

The Area-centralis lens and Mainster standard (now called Mainster Focal/Grid) are excellent lenses for macular photocoagulation.

Patient fixation is used to locate the foveal center.

Focal vs Grid laser

Local treatment for CSME consists of direct focal treatment, grid treatment or a combination of direct and grid treatments. If the oedema is diffuse, grid laser is applied. If the leakage affects a small part of the macula, as in circinate retinopathy, focal laser is applied.

Focal laser

All focal leaks (mainly microaneurysms) located between 500μ -3000μ from the centre of the macula that contribute to retinal thickening and/or lipid exudates are treated directly with 100μ spots at 0.1 sec duration to produce a very light subtle white burn. Try a test burn in a non-critical paramacular area with increasing power to determine power settings. The usual starting point is 80 to 200 mw. The end point of laser is an immediate blanching of larger microanurysms.

Laser may induce changes in the metabolic activity of the retinal pigment epithelium and cause the release of signals that reduce vascular leakage and facilitate fluid absorption. Although spot sizes as small as 50 µm were used in the ETDRS 5 , a 50-µm spot increases the power density and may increase the risk of breaks in Bruch's membrane and secondary choroidal neovascularization. If macular oedema persists on follow up examination,focal leaks located within 300-500 from the centre may also be treated provided there is a good perifoveal network.

Grid treatment

This type of laser is aimed directly at the affected area or applied in a contained, grid-like pattern to destroy damaged eye tissue and clear away scars that contribute to blind spots and vision loss. This method of laser treatment generally targets specific, individual blood vessels.

All areas of thickened retina within the arcades that show diffuse fluorescein leak or capillary dropout are treated with 100µ -200µ spot size placed one burn width apart at 0.1sec duration. The end point of each laser burn used in a grid pattern is a light intensity barely visible burn. Low power (often 80-100 mw) is needed for pseudophakia and clear media; higher power is needed if there is a cataract or marked retinal thickening. (Usually <180mw). It is difficult to know how heavy to make the laser, but burns that do not show on a fluorescein angiogram later were probably too light, so you can tell retrospectively. Burns that were too heavy cause significant atrophy. Even 'perfect' burns may produce very slight pigmentation, but significant pigmentation indicates excessive power. Usually ideal burns are visible 1 minute after the laser. The laser burns must be at least 500µ from foveal centre and 500µ from disc margins. Treatment within the papillomacular bundle is usually avoided. Any focal leaks within the zone of grid treatment are treated focally. In cases where the oedema is limited to certain sectors of the macula, it is important that the laser is not done all over the macula but only in the thickened areas showing dye leak (Modified Grid).6

Re-Treatment

Revaluate the patient every 4 weeks. If after 8-12 weeks, there are areas of thickening (i.e. edema) still present; give a little touching to all leaking areas (repeat FFA is done before this) upto 250 microns from the foveal centre. Lipid exudates may initially increase as fluid is reabsorbed and precipitation of lipid occurs. Exudates can also persist for many months after absorption of fluid; therefore associated thickening must be present if re-treatment is considered. Most patients require more than one treatment session (one to three on an average), for macular edema to resolve. CSME requiring more than 3 treatment sittings becomes recalcitrant and requires alternative pharmacological agents.

Table 1: Clinical Guidelines

Clinically Significant Macular Edema (CSME) Treatment

First-line therapy

- Focal or modified ETDRS grid photocoagulation for focal or diffuse CSME
- Intravitreal pharmacotherapies ± photocoagulation for more advanced, diffuse CSME

Repeat photocoagulation

For persistent or recurrent CSME (visual acuity <20/40) Intravitreal triamcinolone acetonide or intravitreal antivascular endothelial growth factor (VEGF) agent

For CSME refractory to photocoagulation and intravitreal pharmacotherapies, consider pars plana vitrectomy (PPV)

No traction: PPV with internal limiting membrane (ILM) peeling

Taut posterior hyaloid face or vitreomacular traction syndrome:PPV

Complications

- Photocoagulation of the fovea-This is the most-feared complication of macular laser treatment. Loss of foveal function can occur after direct laser treatment of the fovea or from "creep" of a juxtafoveal laser scar into the fovea.
- Secondary CNVM-A larger spot size decreases the power density and reduces the risk of this complication. We always start at the lowest power setting and gradually increase until the lightest color change is observed.
- Paracentral scotomas- Avoided by lower-intensity spots.
- Mydriasis due to sphincteric damage if pupil was not well dilated or due to damage to nerves in uveal tract. It is usually permanent.
- Paralysis of accommodation- usually temporary

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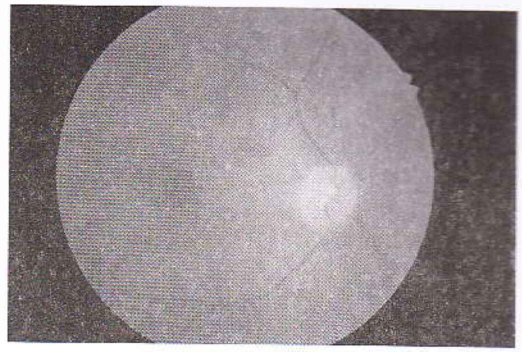

Figure-1 showing CSME

Figure -2 FFA showing diffuse macular edema

Figure -3 FFA showing ischaemic Maculopathy with IRMA

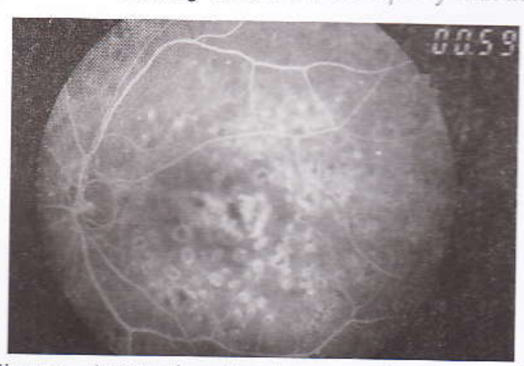

Figure -4 FFA showing laser spots at macula